Computer Networks
Architecture and Protocols

Supplementary Class Notes

Operating System
CS 43201
CS 53201

Contents

Network Architecture

- A set of nodes (hosts) and a set of links (transmission lines).
- Two extreme configurations:
  - Fully connected networks with N nodes.

$$\text{number of connections} = \frac{N(N-1)}{2}$$

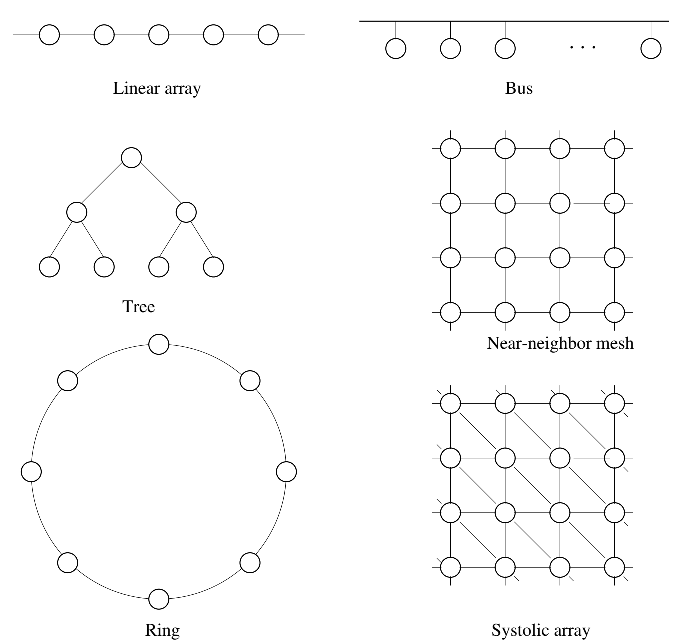
  - Star networks: with N nodes and an intermediate switch.

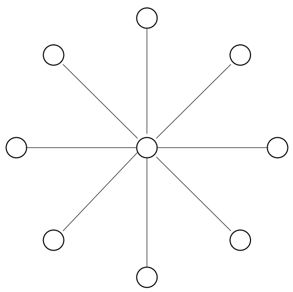
$$\text{number of connections} = N$$

- Most real networks have arbitrary topology.

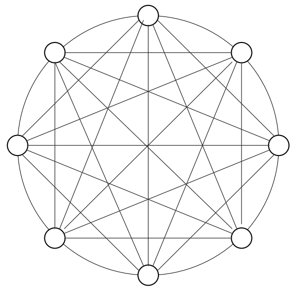
Topological Classification

- Static networks
  - 1-D (bus)
  - 2-D (tree, stars, rings, mesh, etc.)
  - Multidimensional (cube, hypercubes)
- Dynamic networks
  - One or more switches are used.

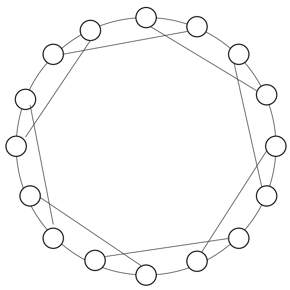




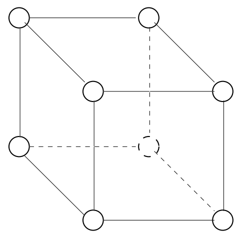
Star



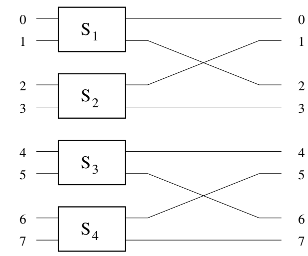
Completely connected



Chordal ring



3-cube



An example of an 8 x 8 single stage dynamic network

Technological Classification

- Circuit-switching networks
  - A dedicated path is used between a source and a destination.
  - No queuing
  - Example: telephone systems.
- Packet Switching
  - The message is divided into a number of slices called packets of certain fixed size.
  - Each packet has its destination address.
  - Queuing involved
  - Routing is needed
  - Errors involved
- Message Switching
  - The network receives the entire message, stores it in a secondary storage and then transmits it.
  - It provides a long term storage even after the message has been delivered.
- Non-Switching Networks.
  - Broadcast networks
  - Single node, data processing(1-800).

  - Single node, data base management (library).

Computer Networks

- Wide Area Networks
  - Bandwidth is scarcest resources
  - Store/forward used to ensure optimal bandwidth utilization
  - Burden on hosts and nodes to conserve bandwidth
  - Most WANs use point-to-point links except for satellite networks.
- Metropolitan Area Networks
  - Intended for interconnection of LANs
  - MANs typically span entire country.
  - Owned by multiple organizations.
  - Covers the entire city but uses LANs technology (CATV).
- Local Area Networks
  - Unlimited bandwidth
  - Hosts are simple machines
  - Lighter burden on hosts
  - Most LANs use a multiaccess channel.
  - A diameter $<$ a few km.
  - Total data rate of at least several Mbps.
  - Complete ownership by a single organization.

Difference between LANs and WANs

- Designers of WANs are always forced by legal, economic or political reasons to use PSN regardless of it technical suitability.
- LAN cables are highly reliable.
- Error rate is 1000 times lower than WAN.
- In WANs, error handling must be done in each layer.

Network Architecture

- A network consists of a series of levels called layers.
- A protocol is the rule of communication; each layer has its own protocol.
- Each computer and/or each application program in the computer may require a different communication access method and protocol.
  - They setup a session through the network.
  - They must agree on the format.
  - Terminals must be able to regulate data rates
  - Packets may arrive out of order.

Network Standardization

- In the early days, different vendors had different networks.
- Standards fall into two categories:
  - De facto standard
    - Have just happened without formal plan.
    - IBM PC, UNIX, DOS.
  - De Jure standard (by law)
    - Formal legal standards
- De Jure standards are two classes.
  - Those established by treaty among national governments,
  - Voluntary non-treaty organizations.

Transmission Standards

- Voice transmission is still the most common mode of communications.
- All projections indicate that voice will continue to be the heaviest communications.
- AT&T in early 1960s introduced digital carrier system T1
  - Consists of 24 channels at 64 Kbps per channel.
  - 1.544 Mbps.

  - US, Canada and Japan.
- CCITT has 30-voice channel at 2.048 Mbps (rest of the world).
- The great interest is transmitting packetized voice in real time.

IEEE Standard 802 for LANs and MANs

- IEEE 802 has been adopted by ANSI, NIST, and ISO
- IEEE 802.1 gives and introduction to the set of standards and defines the interface primitives.
- IEEE 802.2 describes the upper part of the data link layer (LLC)
- IEEE 802.3 describes CSMA/CD with its MAC protocol.
- IEEE 802.4 describes token bus with its MAC protocol.
- IEEE 802.5 describes token ring with its MAC protocol.
- IEEE 802.6: Distributed Queue Dual Bus for MANs

Layered Architecture

- IBM SNA was one of the first layered architecture.
- OSI of ISO rapidly became an international standard.
- In layered architecture, Protocols must appear in every network node.
- The bottom 3 layers of OSI provide network services and the upper 4 layers provide services to the end users.

OSI Layers

1. Physical Layer
   - Performs direct transmission of logical information into physical phenomena (electronic pulses).
   - Modulators/demodulators are used at this layer.
2. Data Link Layer
   - Makes sure that the message indeed reach the other end without corruption (signal distortion and noise).
   - Acknowledgments
   - Detect duplications.
   - Timers for retransmission.

3. Network Layer
   - Controls routes for individual message through the actual topology.
   - Finds the best route.
   - Finds alternate routes.
   - Buffering and deadlock handling.
4. Transport Layer
   - Locates the other party
   - Creates a transport pipe between both end-users.
   - Breaking the message into packets and reassembling them at the destination.
   - Applies flow control to the packet stream.
5. Session Layer
   - Is responsible for the relation between two end-users.
   - Maintains the integrity and controls the data exchanged between the end-users.
   - The end-users are aware of each other when the relation is established (synchronization).
   - It uses naming and addressing to identify a particular user.
   - Makes sure that the lower layer guarantees delivering the message (flow control).

6. Presentation Layer
   - It translates the language used by the application layer.
   - It makes the users as independent as possible, then they can concentrate on conversation.
7. Application Layer(end users)
   - Where they process information that is being exchanged.
   - The users don't want to be aware of the mechanism of the network.
   - The users shouldn't be bothered by each other's language.

Advantages of Layered Architecture

- Any given layer can be modified or upgraded without effecting the other layers.
- Modulazition by means of layering simplifies the overall design.
- Different layers can be assigned to different standards, committees, and design teams.
- Different mechanisms (packet-switching, circuit-switching) may be used without effecting more than one layer.
- Different machines may be plugged in at different layers.
- The relation between different control functions can be better understood.

- Common lower levels may be shared by different higher levels.
- Functions (especially at lower levels) may be removed from software to hardware and microcodes.
- Increases the compatibility of different machines.

Disadvantages of Layered Architecture

- Total overhead is higher.
- Two communicating machines may have to use certain functions which they could do without layers.
- As technology changes, the functions may not be in the most cost-effective layer.

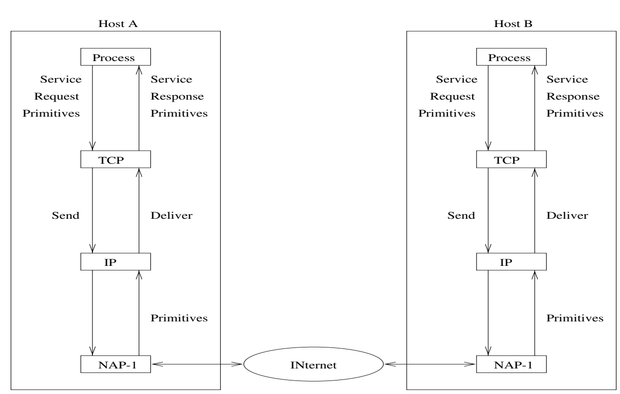
Service Orientations

- Connection-oriented services
  - The sender pushes objects in at one end and the receiver collects them in the same order at the other end.
  - It was modeled after the telephone system.
- Connectionless-oriented services
  - It was modeled after the postal service
  - Packet could take independent routes
  - Packet could be received out of order. Reordering may be required.
  - Datagrams

Network Protocols

TCP/IP

- Was developed to interconnect heterogeneous networks.
- IP resides between the Transport and Network layers of OSI model.
- In this position, IP remains hardware independent.



NAP= Network Access Protocol

Use of TCP/ and IP services primitives

- IP provides connection-less service between nodes or hosts.
- The order of datagrams received is not necessarily in the same order.
- Each datagram is individually routed
- IP can be operated across disjoint network services (connection oriented or connection-less).
- TCP in coordination with IP provide routing, flow control, fragmentation, addressing, and error correction/detection.
- Each datagram has a life-time. A datagram can loop indefinitely.
- During its journey, a datagram can be continually downsized.
- Defragmentation is not performed at intervening gateways.
- IP does not define a standard packet size.

Transmission Control Protocol, TCP

- Developed originally for use in Arpanet.
- TCP in conjunction with IP is a de facto standard for heterogeneous node communications.
- TCP resides in the Transport layer of the OSI model.
- TCP is a connection-oriented protocol.
- TCP operates as an intermediary between applications and the internetwork.

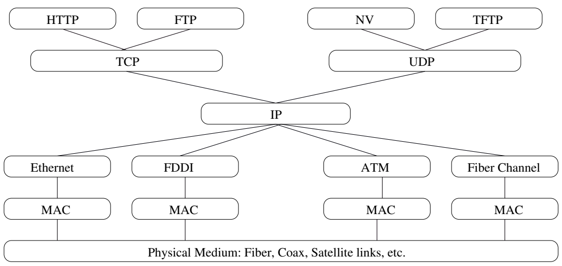
- Since IP is not reliable, TCP assumes that:
  - Segments may be lost or arrive somewhere with errors.
  - Segments may not be received in transmitted order.
  - Segments may be delayed at a variable rate which slows communications.
- TCP sends ACK for each segment it receives.
- If the sending TCP doesn't receive the ACK within a reasonable amount of time, it presumes the lost and res-send.
- TCP establishes a connection (session) between two sockets (nodes), with two purposes:
  - To define all connection characteristics including security.
  - To allow for each TCP socket to maintain state information about the connection (last sequence number used and received, and last sequence number acknowledged).
- TCP has been designed to service multiple processes' requests within a single node.

Internetworking

- So far, we assumed a single homogeneous network, with each machine using the same protocol in each layer. This is not realistic.
- Controversy: whether problems associated with heterogeneous networks will go away or we have to live with it.
- For the time being variety of different networks will be around for the following reasons.
  - The installed base of different networks is large and growing.
  - All Unix shops run TCP/IP.
  - Many large businesses still have mainframes running SNA, DEC, etc.
  - Personal computer LANs often use Novell NCP/IPX or AppleTalk., etc.
  - ATM systems are starting to be widespread.
  - Specialized protocols are often used in satellite, cellular, and infrared networks.
- Within an organization (university), different networks interact.
  - LAN-LAN
  - LAN-WAN
  - WAN-WAN

  - LAN-WAN-LAN
- These connection use one or more of the following black boxes.
  - Repeaters at layer 1
  - Bridges at layer 2
  - Multiprotocol routers at layer 3
  - Transport gateways at layer 4
  - Application gateways allows internetwork above layer 4.

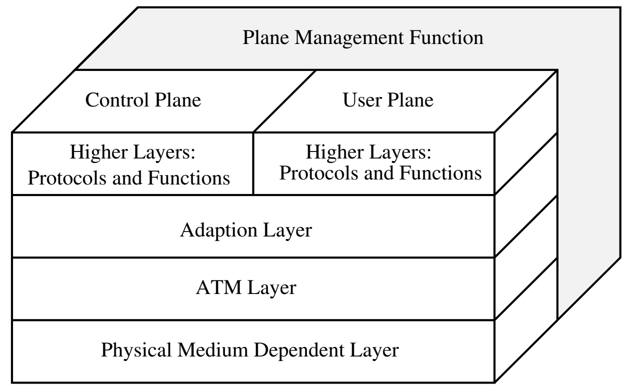
Internet Protocol Hierarchy



- There is no real structure, but several major backbones exist.
- Attached to the backbones are regional (midlevel) networks.
- Attached to regional networks are the LANs at many places.
- The glue that holds the Internet together id the IP protocol.
- Its job is to provide a best way to transport datagrams from source to destination transparently.
- The transport layer takes data streams, breaks them into datagrams.
- Datagrams can be up to 64 KB, but in practice they are usually around 1500 bytes.

Asynchronous Transfer Mode (ATM)

- Connection-oriented packet-switched network
- Used in both WAN and LAN settings
- Signaling (connection setup) Protocol: Q.2931
- Specified by ATM Forum
- Packets are called *cells*: 5-byte header + 48-byte payload
- Commonly transmitted over SONET (but not necessarily)



B-ISDN protocol Model for ATM (CCITT I. 121)